RF Signal Generator

SG8-HP01M

SG8-HPSS01M

Datasheet

Rev. 1.1

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Document Revisions

Rev.	Date	Description
0.1	June 20, 2009	Preliminary data based on the estimated performance of the constituent RF-blocks
0.2	November 28, 2010	Based on the LNO-HP03M-RF block
1.0	July 27, 2011	Based on the measurement of the small-production sample consisting of LNO-HP30M-RF synthesizer and LNO-REF-20M-RF dual reference frequency source block.
1.1	October 17, 2011	Revised REF In sensitivity, AC power consumption, maximum dimensions (with connectors and legs), internal reference frequency temperature effect, revised ADC full scale voltage swing (at unit gain) in table 10.

Specification subject to change without notice.

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1 Overview

1.1 Distinctive Features

- High output power
- Arbitrary reference frequency
- Small size
- Low cost

1.2 Key Features

Short-form specifications are given below. Detailed data and additional conditions for these values are given in section 2 on page 12.

- Output frequency range: **10 MHz – 8 GHz**;
- Frequency resolution: < **0.001 Hz**;
- Spectral purity
  - non-harmonics (typ.):
    - HPSS: **−65 dBc**;
    - HP: **−50 dBc**;
  - harmonics: **−30 dBc**;
  - phase noise: **−120 dBc/Hz** @ 1GHz, 10 kHz offset;
- Output level: up to **+28 dBm**;
- Absolute level accuracy: **±0.1 dB**;
- Output level flatness: **0.2 dBpp**;
- Phase shift control
  - adjusting range: **360°**;
  - min. step: **0.15°** @ 1 GHz;
- External input reference frequency
  - range: **20 – 150 MHz**;
- Remote control: **RS-232**, **USB**;
- Operating temperature: **0..+40 °C**;
- Dimensions: H x W x D: **2U x 42HP($\frac{1}{2}$ 19") x 315 mm**.

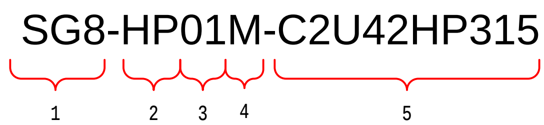


Figure 1: Instrument part numbering

1.3 Part numbering. Hardware & Software Options

The instrument part number consists of the following fields (fig. 1):

1. Instrument series (project name)
2. Hardware options and modification type
3. Revision
4. Assembly variant
5. Case type

Table 1 contains the detailed description of the part number fields and auxiliary options. They appear in part number in the same order as listed in the table. Options mutual compatibility is shown in table 2.

1.4 Applications

General Purpose RF Signal Generator

Instrument frequency range covers the common bands for RF applications such as radio and television, mobile, wireless networks, and radio-relay communications. This makes it possible to use the instrument in testing and debugging applications for all systems listed above. High output power compensates for additional level loss on the way to the DUT. Convenient user interface, large control elements and high-contrast display make it easy to obtain the desired signal at the RF output. Small dimensions and lightweight saves working space and maintains easy portability.

Arbitrary Reference Frequency Generator

Small frequency step combined with low phase noise in low bands allows to use the generator as an arbitrary reference frequency source while testing the deviation tolerance of symbol clock rates and local oscillators of communication systems. Low phase noise at low output frequencies is possible due to frequency dividers used up to the lower bound of the frequency range instead of frequency conversion from high to low range.

One-decibel Compression Point $P_{1\mathrm{dB}}$ Measurement for High-power Output Stages

High output level enables one-decibel compression point and saturated power P_{SAT} measurements without additional

Table 1: Part number fields description

Marking	Description
Field 1. Instrument series	
SG8	RF **S**ignal **G**enerator, up to **8** GHz
Field 2. Hardware options	
HP	**H**igh Output **P**ower, high level accuracy due to APC (Automatic Power Control) loop directly at the output
SS	Additional **S**pur **S**uppression hardware option (LNO-REF-20M-RF)
Field 3. Revision	
01	Instrument revision number①
Field 4. Software options and assembly variants②	
M	Internal reference frequency source 147 MHz③
Field 5. Case type④	
C2U42HP315	Case (“C”) height 2U (88.9 mm), width 42HP (213.36 mm), depth 315 mm

① Instrument revision number is changed when significant modifications concerned the functional characteristics of the instrument were made
② PCB assembly variant, MCU and FPGA firmware revision
③ Default assembly and firmware variant

④ Ordering without case is available on demand (i.e. as a set of blocks: synthesizer, power supply, control PCB board)

Table 2: Options compatibility

		Hardware options	
		HP	SS
Assembly variants	M	✔	✔
Hardware options	SS	✔	

pre-amplifiers. Usually high-power output stages have relatively small gain, so availability of high power at the instrument output sufficiently simplifies the testing process.

Second and Third Order Intercept Point IP_2 and IP_3 measurements

Low nonlinear distortion of output stage, and high output level compensating for additional losses in attenuators following by power combiner, enable intermodulation parameters measurements of almost any RF path.[1]

RF-path Frequency Response Measurements

Good frequency response flatness in wide frequency band due to APC (Automatic Power Control) and digital correction system allows to run scalar network analysis of DUT.[2]

Debugging of the RF Transceiver blocks for Telecommunication and Test&Measurement Equipment

High output level and relatively low phase noise enables to use the instrument as a local oscillator for passive balanced mixers, which usually require high power for ensuring better linearity of the path.

When debugging some systems, it is required that several LO sources in the same path are bound to some reference by natural factor. And reference frequency may significantly differ from standard series of references offered by most signal generators. In this case SG8 can use any frequency as a reference, making no demands to its stability or precision.

Test&Measurement Automation

External control interfaces (RS-232, USB) combined with SCPI protocol allows to use the instrument in ATE applications in volume production as well as in education laboratories where equipment is usually combined to one complex controlled by PC.

1.5 User and Control Interfaces

Figure 2 shows front panel of the instrument.

1. RF Out – RF signal output, N-type connector;
2. RF LED – output “ON” indicator;
3. RF ON/OFF – RF output ON/OFF button;
4. Power ON/OFF button – secondary supply power down;
5. OLED graphical display;
6. Rotary knob;
7. Keyboard;
8. Menu buttons;

Rear panel contains the following items (fig. 3):

[1] This type of measurements assumes the availability of couple instruments
[2] With aid of spectrum analyzer

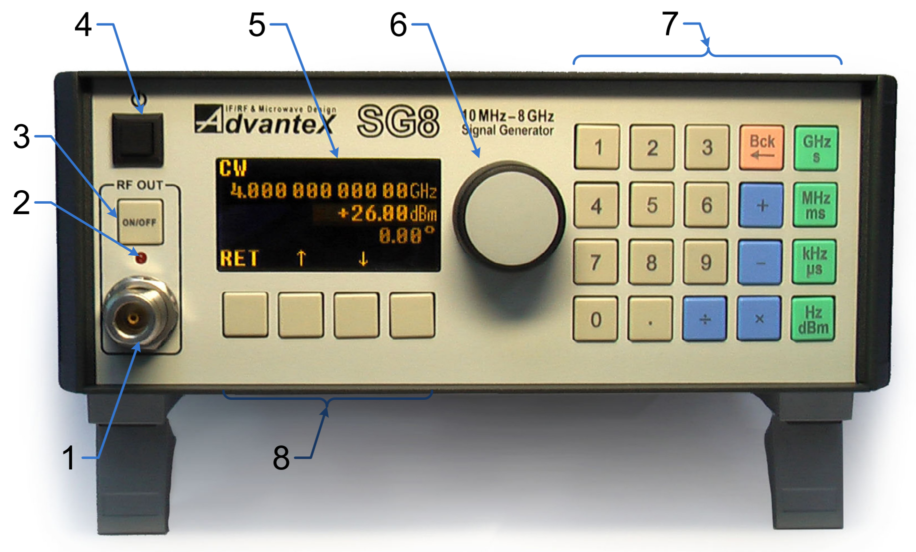


Figure 2: Front panel

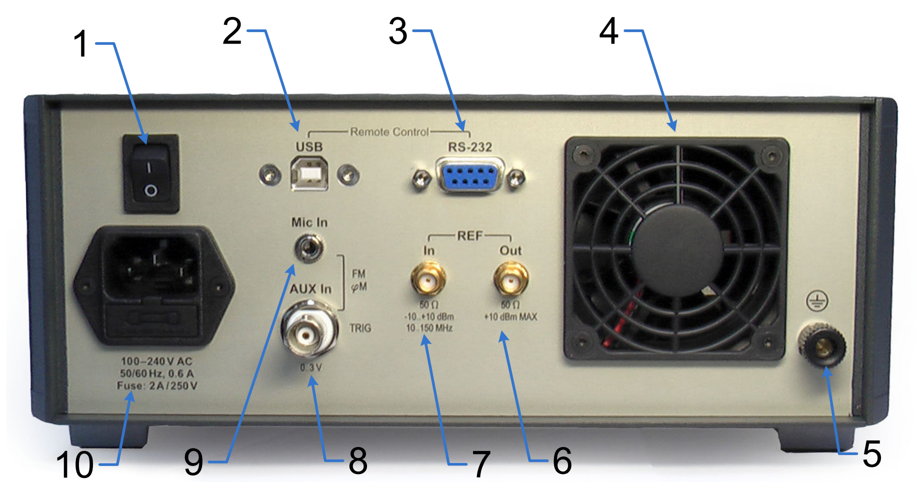


Figure 3: Rear panel

1. ~100-220V AC power OFF switch;
2. USB – type B connector;
3. RS-232 – interface for control via PC COM-port, D-Sub, 9-pin, female connector;
4. FAN;
5. GND – ground terminal;
6. REF Out – reference frequency output, SMA connector;
7. REF In – reference frequency input, SMA connector;
8. AUX In – auxiliary analog/digital TRIG input, BNC connector;
9. Mic In – microphone input;
10. ~100-220V AC power supply connector with fuse.

1.6 Block Diagram

Figure 4 shows the block diagram of the RF-synthesizer, the main block of the instrument. Reference frequency signal is fed to the positive input of phase-frequency detector (PFD) . PFD output signal is fed to the loop-filter, then to the octave VCO control input. Via splitter signal is fed to fixed frequency divider by 8, then to Direct Digital Synthesizer (DDS). Signal from the output of the DDS is being filtered and fed to the negative PFD input, thus closing the feed-back loop of the PLL system. DDS is used in this scheme like frequency divider with very small step of the division factor tuning. VCO output signal is fed further to frequency division block, following by the harmonic filtering block. From the filtering block it's further fed to the automatic power control block (APC), then to the RF Out output. Output amplifier is connected with output connector directly (via APC's splitter), so it allows to gain maximum power at the RF Out which output stage is capable of.

There are some rations of output and reference frequencies at which extra spurs produced by the DDS appear at the output. In order to avoid this effect the switchable reference frequency source can be applied. Figure 5 shows the block diagram of the instrument with additional spur suppression option (SS option). The difference consists of the second reference frequency generation for the RF-synthesizer block. The original reference frequency (147 MHz) from internal TCXO is fed to the PLL with VCXO and very narrow loop filter. PLL forms the second reference frequency 150 MHz. Signals from internal reference source and PLL are connected to the switch and its output is connected with reference frequency input of the RF-synthesizer. Either 147 or 150 MHz is used in accordance with given frequency at the RF Out output. The selection of the reference frequency is automatically controlled by the instrument to obtain least possible spur level. The accuracy of the output frequency step while reference

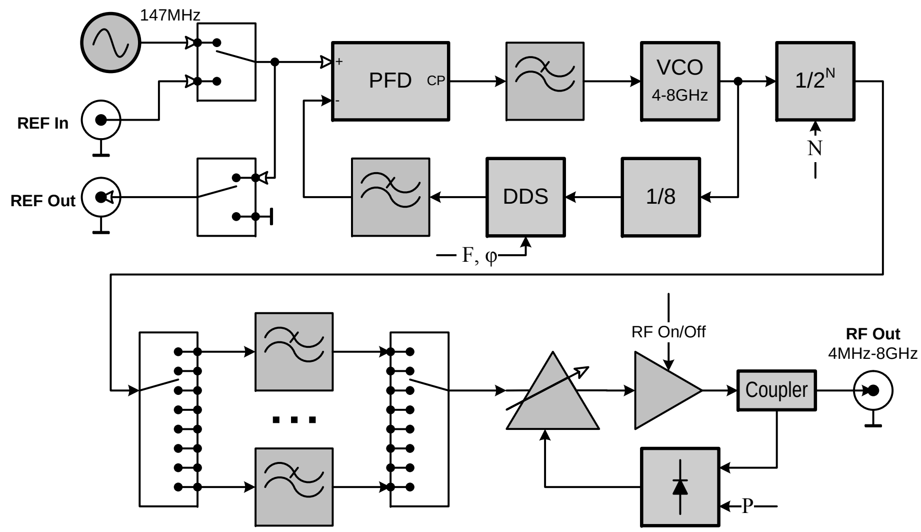


Figure 4: Block diagram of the RF-synthesizer block (HP option)

switching is maintained due to the fixed phase relation between 147 and 150 MHz, and narrow band phase response of the reference PLL allows to preserve the relatively low phase noise level as it would be without additional reference PLL system.

2 Specification

2.1 RF Signal

2.1.1 Frequency Parameters

Output frequency grid is defined by the following equation

$$f_{out} = \frac{2^{51}}{K \cdot M} \cdot f_{ref}, \tag{1}$$

where K (output divider) is given by the table 3, f_{ref} – reference frequency, M – variable integer in range $M_{min} \leq M \leq M_{max}$, minimum and maximum bounds are stated by the following

$$M_{min} = 2^{48} \cdot \frac{f_{ref}\,[\text{Hz}]}{10^9},\ M_{max} = 2 \cdot M_{min}.$$

Minimum frequency step can be found as the derivative of the equation 1:

$$\frac{df_{out}}{dM} = -\frac{2^{51}}{K \cdot M^2}. \tag{2}$$

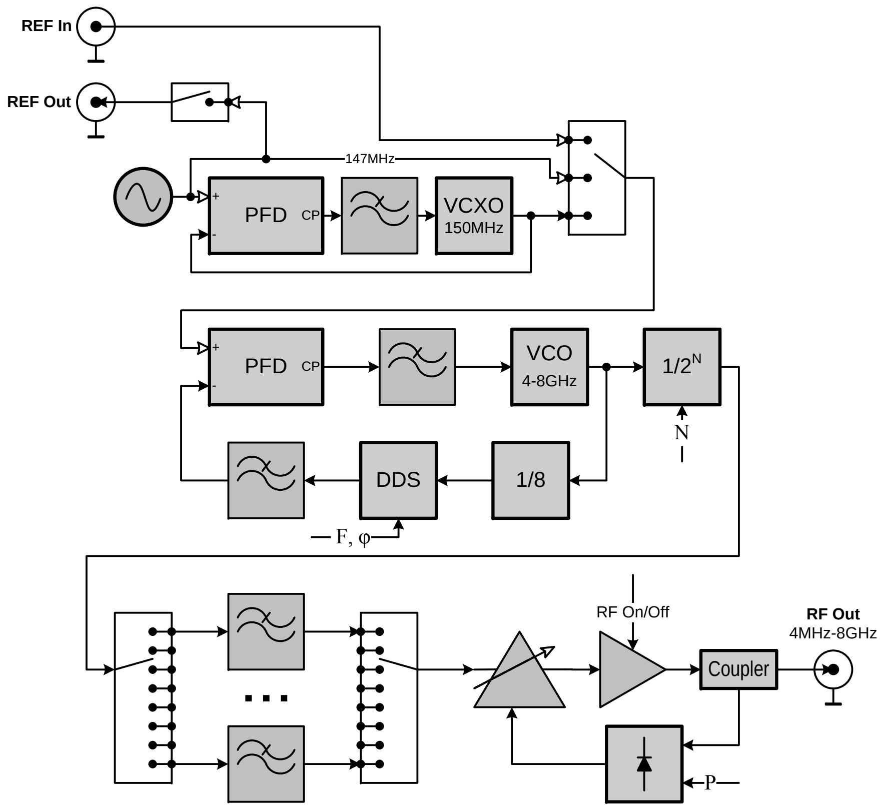


Figure 5: Block diagram of the RF-synthesizer with reference PLL (additional SS option)

Table 3: Divider factor K vs. output frequency

f_{out}, MHz	3.90625-7.8125	7.8125-15.625	15.625-31.25	31.25-62.5	62.5-125
K	2^{10}	2^9	2^8	2^7	2^6

f_{out}, MHz	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000
K	2^5	2^4	2^3	2^2	2^1	1

Table 4: Frequency parameters of the RF signal

Parameter	Conditions	min.	typ.	max.	Unit
Range		3.90625		8000	MHz
Resolution*	over entire range			0.28	mHz
Settling time	from rising edge at AUX In input (frequency switching over entire range)	2.5		4.5	ms
Phase shift resolution**	$f_{OUT} = f_{REF}$			0.022°	
Max. phase shift step w/o phase discontinuity***	$f_{OUT} = f_{REF}$		50°		

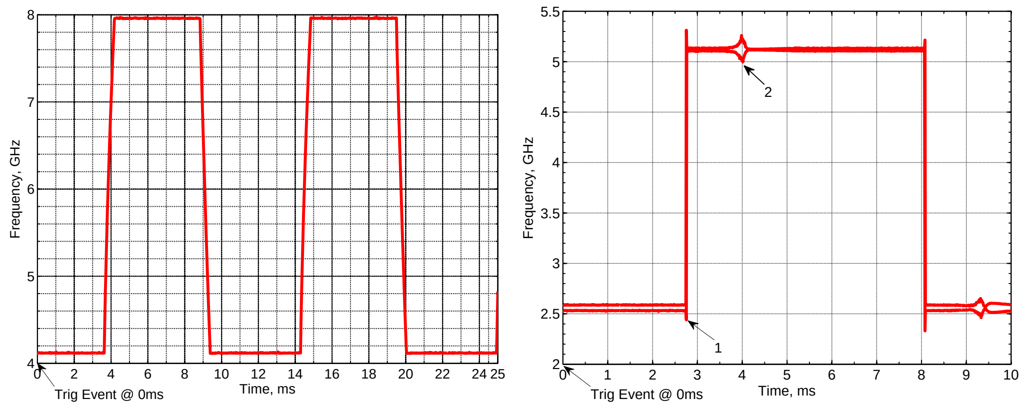
* For any given reference minimum step can be found from equation 2
** Phase shift resolution equals $\Delta\varphi = \frac{360°}{2^{14}} \cdot f_{out}/f_{ref}$, where f_{out} – output frequency, f_{ref} – reference frequency
*** Maximum phase shift step at any given output frequency $\Delta\varphi_{max} = \Delta\varphi_{ref} \cdot f_{out}/f_{ref}$, where f_{out} – output frequency, f_{ref} – reference frequency, $\Delta\varphi_{ref}$ – maximum phase shift step at $f_{out} = f_{ref}$

Key frequency parameters are shown in table 4 for $f_{ref} = 147\,\text{MHz}$ (assembly variant "M") at $T = 25°C$ (unless otherwise noted). Table 5 contains reference specification, which defines stability, table 6 – spectral characteristics of output signal, table 7 – frequency sweep mode parameters, figure 6 – frequency switching process in time domain. Figure 8 shows 2-nd and 3-rd harmonics relative to the first one. Subsequent harmonics have a lower level. Figures 9, 10 show phase noise of output signal.

2.1.2 Amplitude parameters

Table 8 contains RF output level parameters at $T = 25°C$ (unless otherwise noted). Figure 14 shows VSWR and return loss S11 at RF Out output. Table 9 contains characteristics of sweep level mode. Figures 16, 17 show level switching process in time domain at rising edge of triggering signal at AUX In input, figure 15 shows sweep level process (in SWL mode). Figure 11 shows maximum and minimum signal levels vs. frequency, as well as calibration area[3] and actual signal level vs. frequency at various levels set to the instrument.[4] Figure 12 shows absolute output level error within calibration area. Figure 13 shows output signal rejection when RF Out is OFF.

[3]When setting values beyond calibration area the message "UNC" (uncalibrated) appears in status bar on the screen
[4]This figure shows an example of the calibration area, actual calibration bounds may differ from part to part.



(a) Switching within the band stated by table 3

(b) Switching frequency from f_0 to $2f_0$ (while crossing the border of the range in table 3), 1 – switching of the divider, 2 – loading frequency to DDS

Figure 6: Frequency switching process in time domain

Table 5: Reference frequency

Parameter	Conditions	min.	typ.	max.	Unit
Internal reference frequency source					
Frequency			147		MHz
Accuracy	at 25°C		±5		ppm
Temperature effect	0..+55°C		±5		ppm
Reference frequency output (REF Out)					
Output impedance			50		Ω
Signal level (internal source)	SG8-HP	−3.5	0	+4.5	dBm
	SG8-HPSS	−5		+5	
Gain (when repeating external source fed to REF In input)	SG8-HP	−1		+1	dB
External reference frequency input (REF In)					
Input impedance			50		Ω
Level	see figure 7	−10		+10	dBm
Frequency		20		150	MHz
Spur level	$\lvert f_{offset}\rvert \leq 1\,\text{MHz}$, $f_{ref} = 10\,\text{MHz}$			−70	dBc
	$\lvert f_{offset}\rvert \leq 1\,\text{MHz}$, $f_{ref} = 100\,\text{MHz}$			−60	dBc

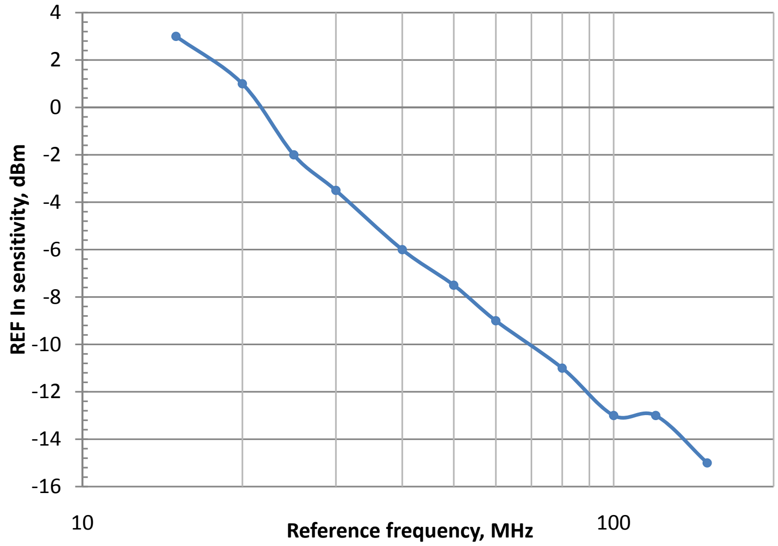


Figure 7: REF In sensitivity

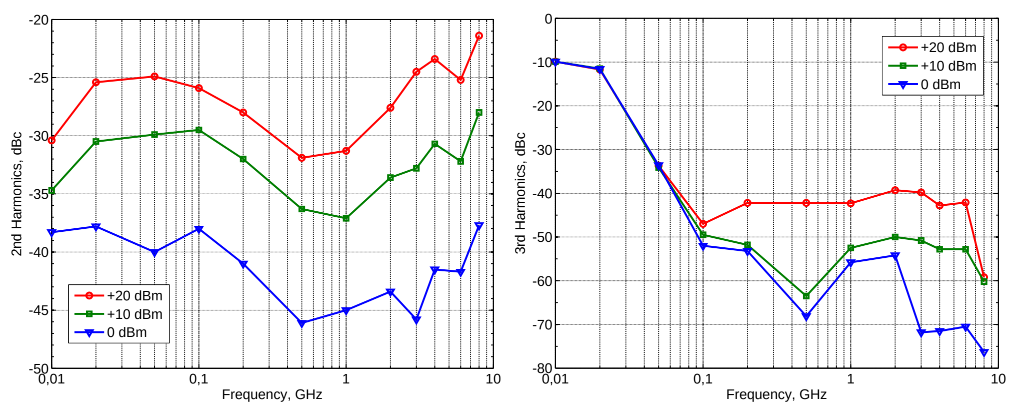


Figure 8: The suppression of second and third harmonics relative to the fundamental frequency of the first (main) harmonic at different output levels

Table 6: Spectral characteristics

Parameter	Conditions	min.	typ.	max.	Unit
2-nd Harmonic ($10\,\text{MHz} \le f_{OUT} \le 8\,\text{GHz}$)	$P_{OUT} = 0\,\text{dBm}$		−40	−35	dBc
	$P_{OUT} = +10\,\text{dBm}$		−30	−25	dBc
	$P_{OUT} = +20\,\text{dBm}$		−25	−20	dBc
3-rd Harmonic ($100\,\text{MHz} \le f_{OUT} \le 8\,\text{GHz}$)	$P_{OUT} = 0\,\text{dBm}$		−60	−50	dBc
	$P_{OUT} = +10\,\text{dBm}$		−50	−45	dBc
	$P_{OUT} = +20\,\text{dBm}$		−40	−35	dBc
Non-harmonics*, $4\,\text{GHz} < f_{OUT} \le 8\,\text{GHz}$	SG8-HP, $\lvert f_{offset}\rvert \le 1\,\text{MHz}$, $P_{OUT} \ge +0\,\text{dBm}$		−50		dBc
	SG8-HPSS, $\lvert f_{offset}\rvert \le 1\,\text{MHz}$, $P_{OUT} \ge +0\,\text{dBm}$		−65		dBc
	$\lvert f_{offset}\rvert \ge 1\,\text{MHz}$, $P_{OUT} \ge +0\,\text{dBm}$		−70		dBc
Far offset noise level	$\lvert f_{offset}\rvert \ge 10\,\text{MHz}$, $P_{OUT} = +20\,\text{dBm}$, $f_{OUT} = 8\,\text{GHz}$		−145	−140	dBc/Hz
Phase noise, $P_{OUT} = +20\text{dBm}$, $f_{OUT} = 1\,\text{GHz}$, @ offset:	1 kHz		−114		dBc/Hz
	10 kHz		−120		dBc/Hz
	100 kHz		−120		dBc/Hz
	1 MHz		−132		dBc/Hz
	10 MHz		−135		dBc/Hz
RMS Jitter	$f_{OUT} = 8\,\text{GHz}$, BW from 1 kHz to 10 MHz		70		fs
Residual FM			2.8		kHz
Residual φM			0.2		deg
Integral phase noise			−52		dBc

* At lower frequency bands the non-harmonics level is improved (i.e. decreased) in proportion to −6 dB per octave

Table 7: Frequency sweep mode

Parameter	Conditions	min.	typ.	max.	Unit
Range		3.90625		8000	MHz
Dwell time		0.001		2	s
Resolution			0.1		ms

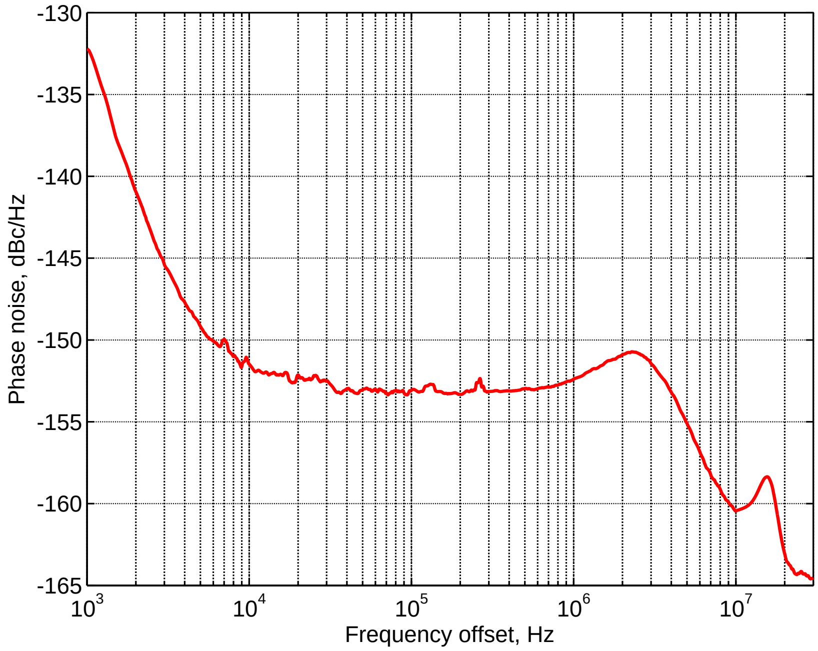


Figure 9: Phase noise of internal reference frequency source at REF Out output (147 MHz)

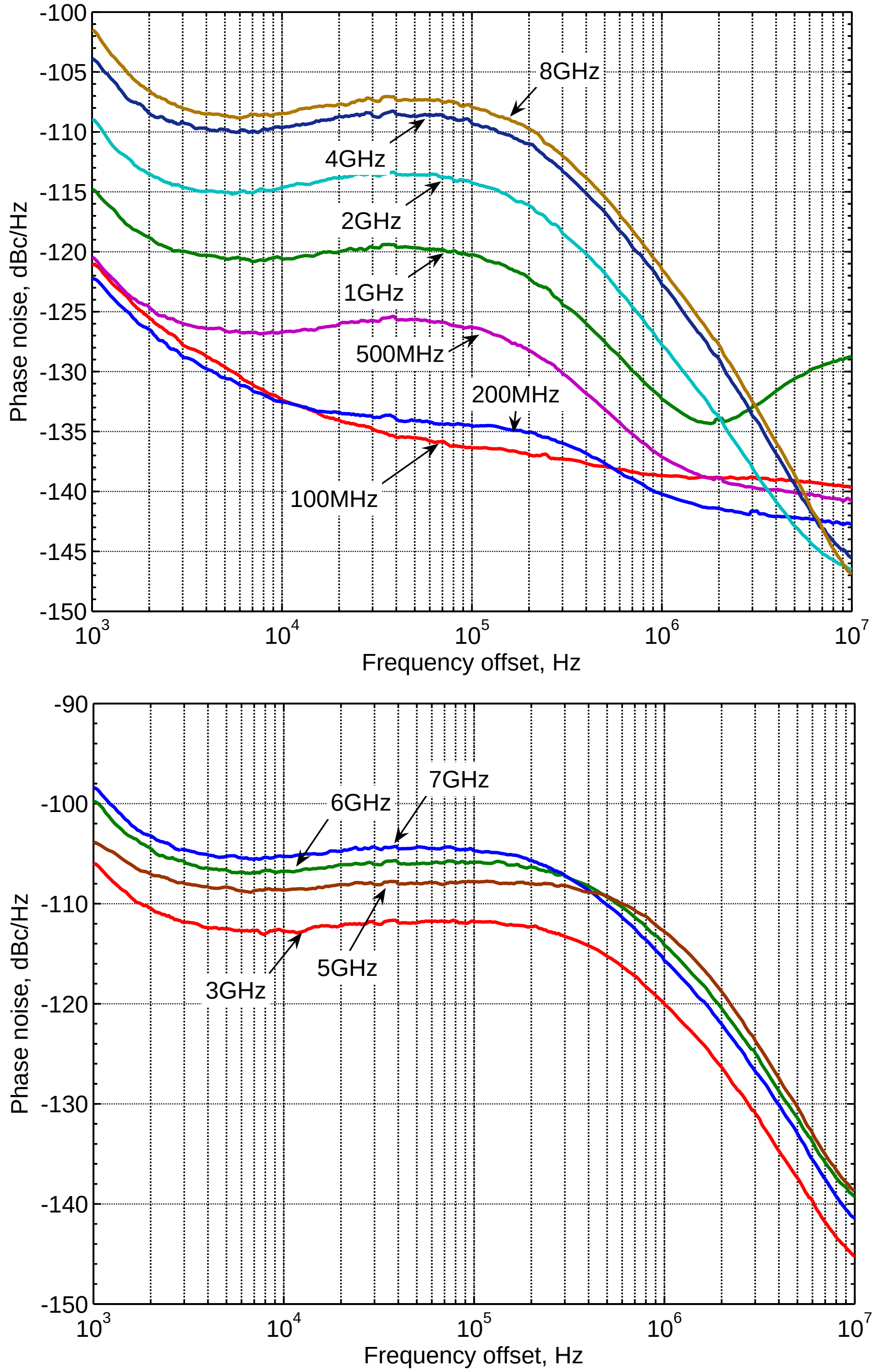


Figure 10: Phase noise of RF output signal

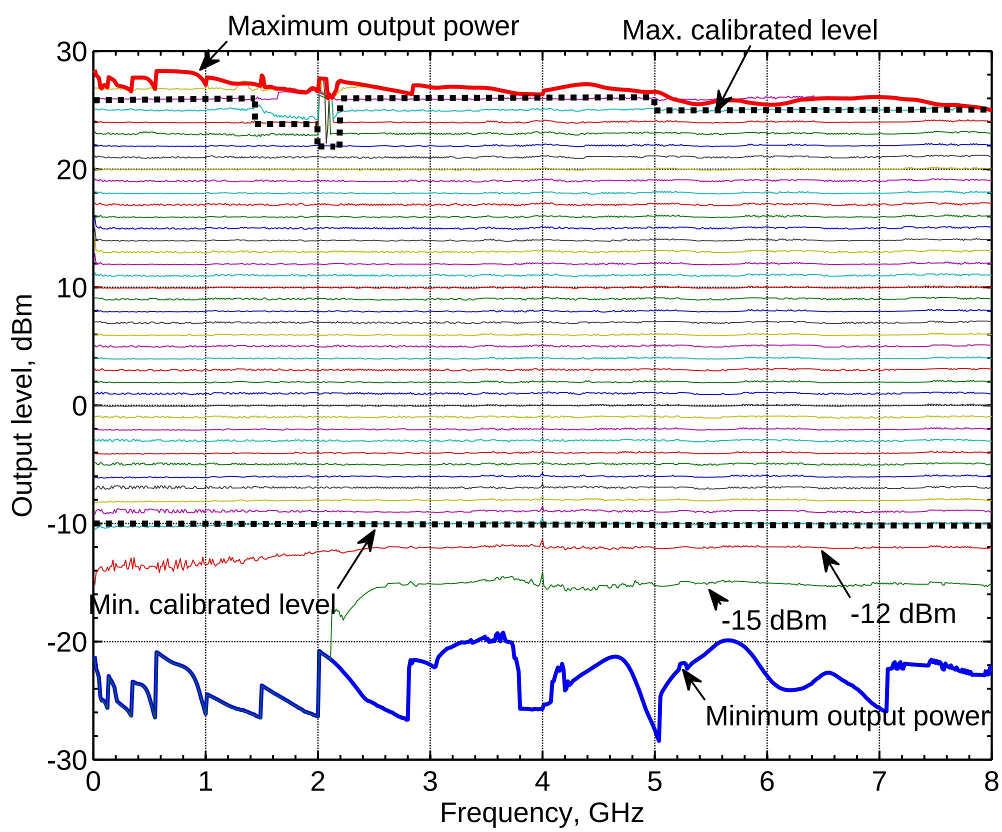


Figure 11: Actual signal level vs. frequency at various levels set to the instrument

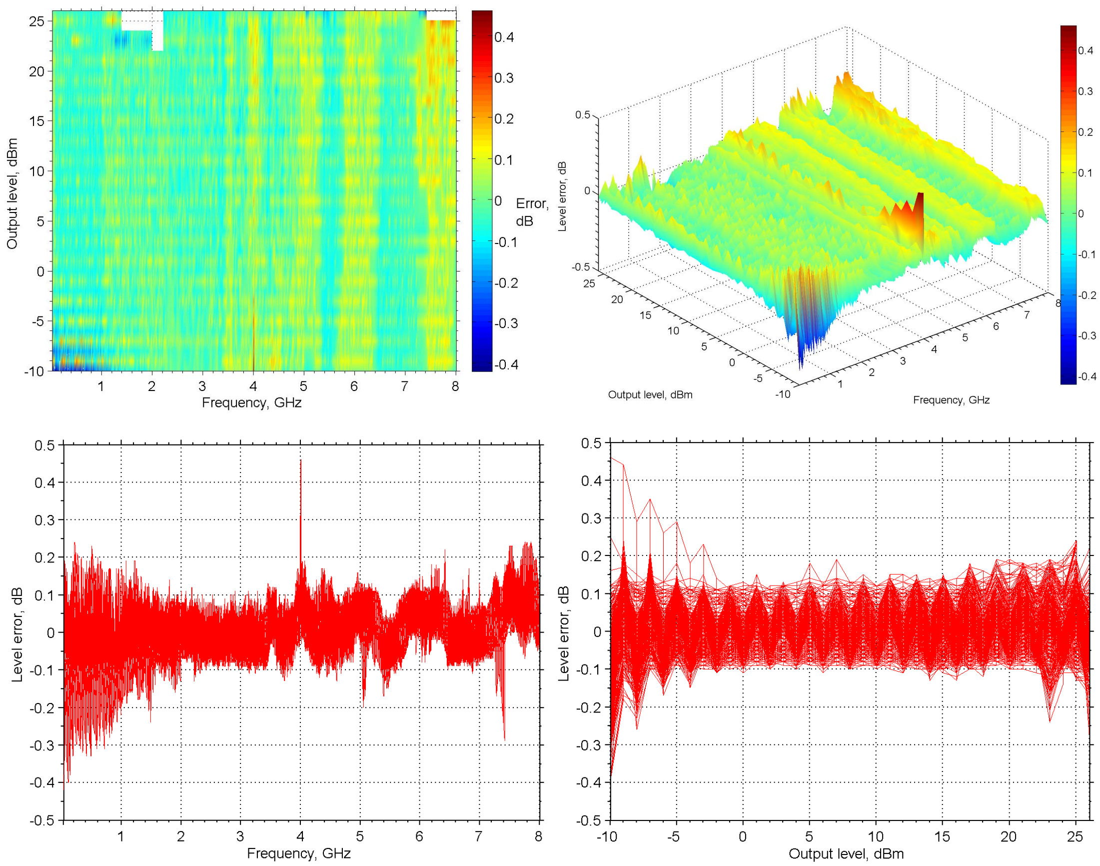


Figure 12: Absolute level accuracy (within calibration area)

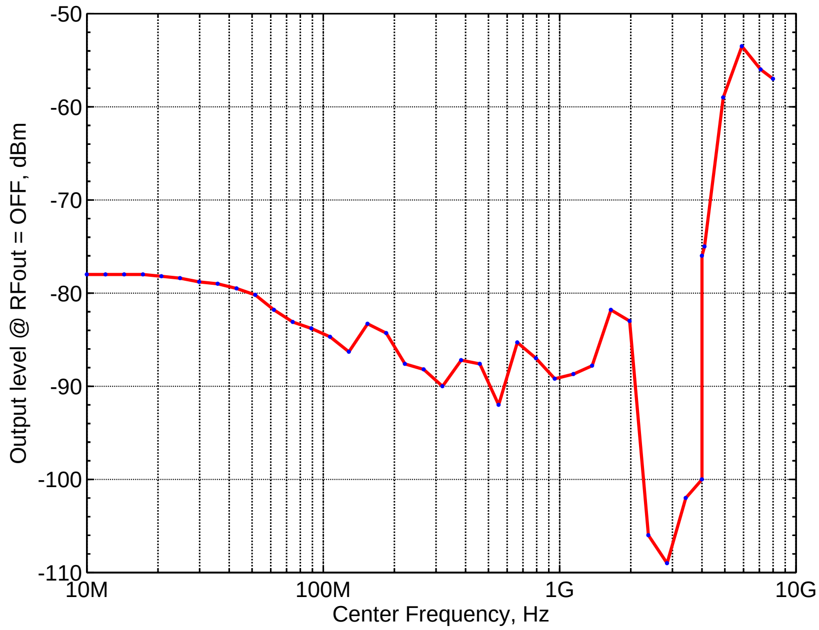


Figure 13: Output power at RF Out = OFF vs. frequency

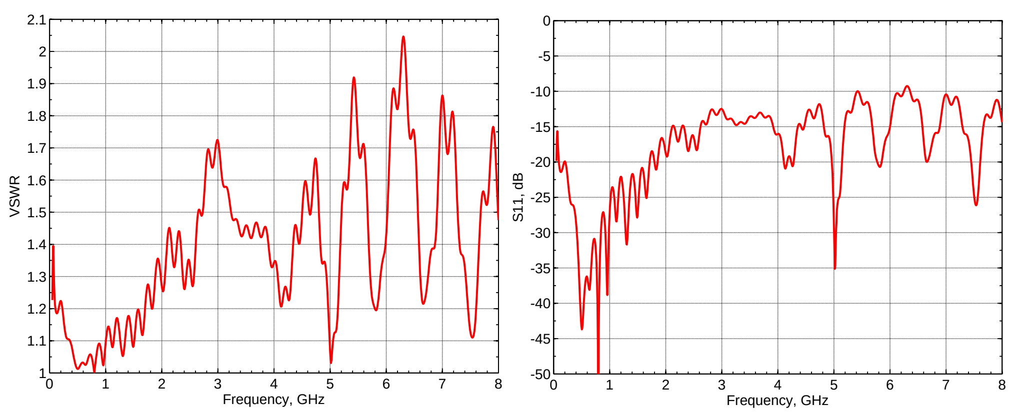


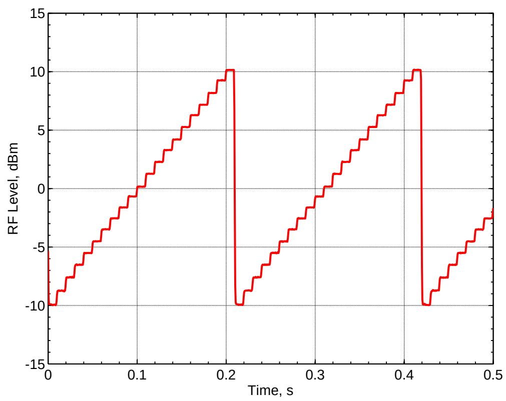
Figure 14: VSWR and return loss at RF Out

Table 8: Amplitude parameters of RF signal

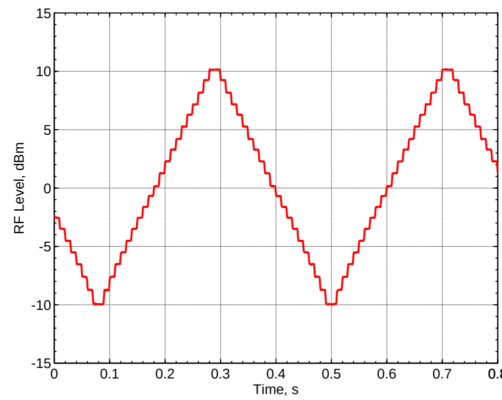
Parameter	Conditions	min.	typ.	max.	Unit
Range		−20		+28	dBm
Calibrated area (APC loop lock range)	max.	−10		+26	dBm
	min.	−10		+22	dBm
Resolution			0.05		dB
Absolute level accuracy	25 MHz $< f_{OUT} \leq$ 8 GHz $0 \leq P_{OUT} \leq 20$ dBm		±0.1	±0.2	dBm
	25 MHz $< f_{OUT} \leq$ 8 GHz for P_{OUT} within calibration area		±0.3	±0.5	dBm
Temperature effect			0.01		dB/°C
Level flatness	25 MHz $< f_{OUT} \leq$ 8 GHz $0 \leq P_{OUT} \leq 20$ dBm		0.2	0.3	dBpp
	25 MHz $< f_{OUT} \leq$ 8 GHz $0 \leq P_{OUT} \leq 20$ dBm in band $\Delta f \leq 25$ MHz		0.1		dBpp
VSWR (50 Ω load)	50 MHz $< f_{OUT} \leq$ 8 GHz		1.8	2.1	
Settling time	from rising edge of triggering signal at AUX In input, when switching within 20 dB from initial level value	2	2.5	3	ms
Reverse power				1	W
Acceptable DC voltage at RF Out		0		8	V

Table 9: Sweep level mode parameters

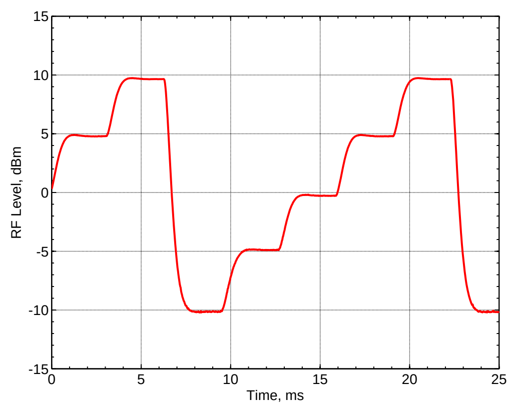
Parameter	Conditions	min.	typ.	max.	Unit
Range	10 MHz $< f_{OUT} \leq$ 6 GHz	−10		+25	dB
	6 GHz $< f_{OUT} \leq$ 8 GHz	−10		+22	dB
Dwell time		0.0032		2	s
Resolution			0.1		ms



(a) Saw, step 10 ms, 1dB



(b) Triangle, step 10 ms, 1 dB



(c) Saw, step 3.2 ms, 5 dB

Figure 15: Sweep level mode (Fc=1 GHz)

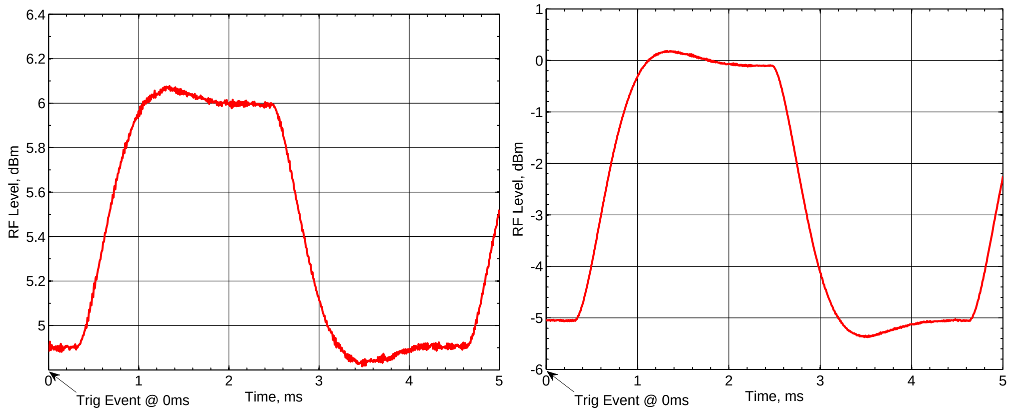


Figure 16: Transient level change at 1 and 5 dB

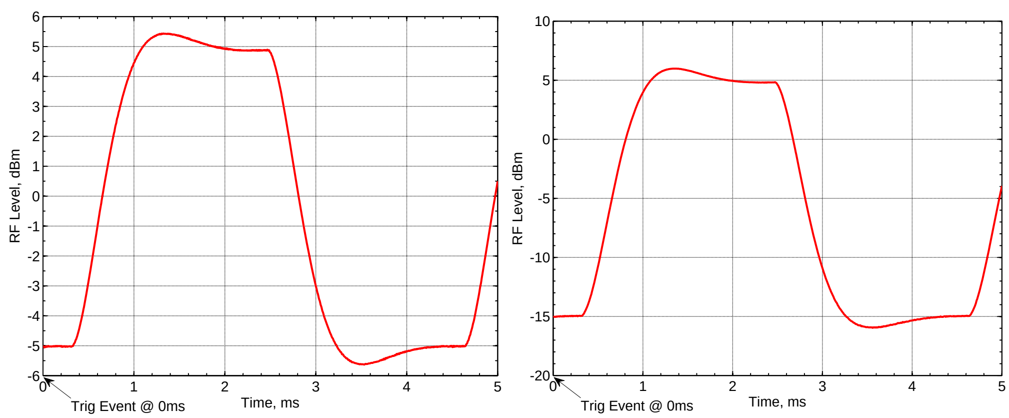


Figure 17: Transient level change at 10 and 20 dB

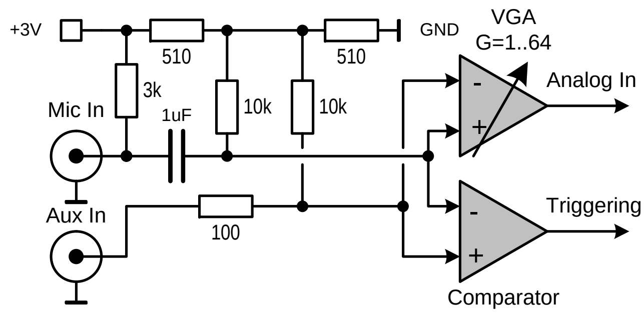


Figure 18: AUX In and Mic In inputs circuit

2.2 Modulation

The instrument supports two types of analog modulation: frequency (FM) and phase (PhM) modulation. Either internal (sinusoidal or rectangle waveform) or external source can be used as the modulating signal. Signal from external source can be applied to AUX In or Mic In inputs. The signals from these inputs are sampled by the ADC and are used for frequency and phase control in digital form. AUX In and Mic In inputs specification is shown in table 10, figure 18 shows input path schematic.

2.2.1 Frequency Modulation

Frequency modulation parameters are listed in table 11. Maximum frequency deviation is defined by the central frequency location with respect to the output divider frequency bounds (table 3). In this case some VCO margin is used. It is about $0.025 \times f_L$ and $0.035 \times f_H$, where f_L and f_H – are lower and upper bounds of output frequency divider respectively. To ensure proper operation, the constraint equal to $1/64$ of center frequency is enforced. For example for 1 GHz center frequency maximum deviation will be about 15 MHz.

Figures 19, 20, 21 show demodulated signal and its spectrum.

2.2.2 Phase Modulation

Phase modulation parameters are listed in table 12. Maximum phase deviation can be found out in the same way as the phase shift control range defined by table 4.

Figures 22, 23 show demodulated signal and its spectrum.

2.3 Remote Control Interfaces

The instrument is supplied with RS-232 and USB interfaces. Any of these can be used for remote control via SCPI protocol, as well as for instrument's firmware

Table 10: AUX In and Mic In inputs parameters

Parameter	Conditions	min.	typ.	max.	Unit
ADC mode (used in modulation)					
Input frequency band	AUX In	DC		100	kHz
	Mic In	0.1		100	kHz
Sampling rate		6	10	10	kHz
Resolution			12		bit
Input impedance	AUX In*		10		kΩ
	Mic In**		3		kΩ
ADC full scale voltage swing	at unit gain			±1	V
Input DC offset corresponding to zero ADC value			1.5		V
Gain control range	2^n grid	×1		×64	
Comparator mode (used for triggering)					
Delay	AUX In		1		µs
Voltage range		0		3	V
DC offset			1.5		V
Hysteresis			50		mV

* +1.5V internal pull-up
** +3V internal pull-up

Table 11: Frequency modulation of RF signal

Parameter	Conditions	min.	typ.	max.	Unit
Frequency range of modulating signal	internal source	DC		2.5	kHz
Maximum deviation	f_C – center frequency		$\frac{1}{64} \times f_C$		Hz
Slope	programmable			$\frac{1}{64} \times f_C$	Hz/V

Table 12: Phase modulation of RF signal

Parameter	Conditions	min.	typ.	max.	Unit
Frequency range of modulating signal	internal source	DC		2.5	kHz
Slope*	$f_{out} = f_{ref}$			50	deg/V
Maximum phase change rate			1.2		kHz

* Maximum slope is increased in proportion to f_{out}/f_{ref}

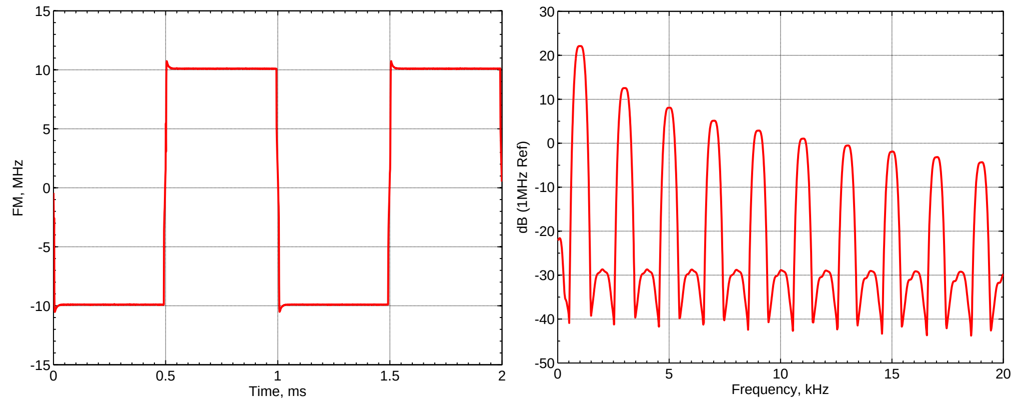


Figure 19: Demodulated FM-signal and its spectrum (internal modulating source, square waveform, frequency 1 kHz, deviation 10 MHz, center frequency 1 GHz)

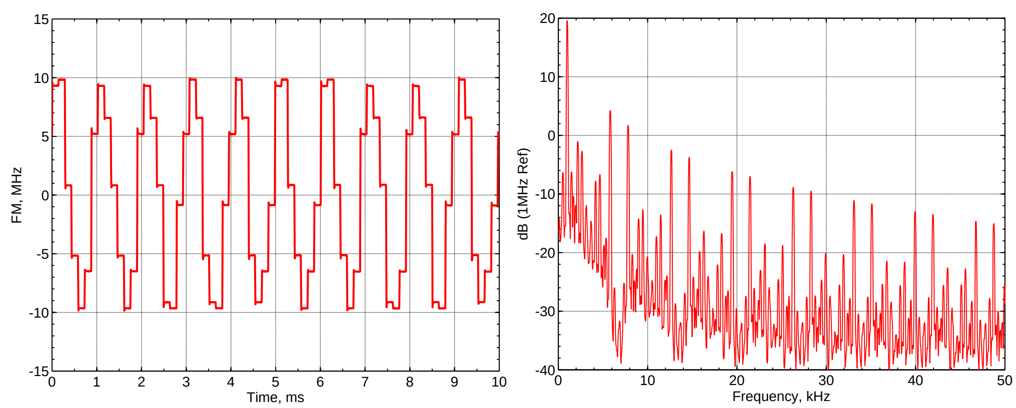


Figure 20: Demodulated FM-signal and its spectrum (internal modulating source, sine waveform, frequency 1 kHz, deviation 10 MHz, center frequency 1 GHz)

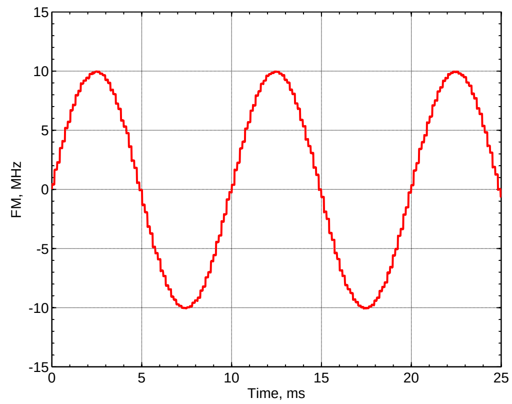


Figure 21: Demodulated FM-signal and its spectrum (internal modulating source, sine waveform, frequency 100 Hz, deviation 10 MHz, center frequency 1 GHz)

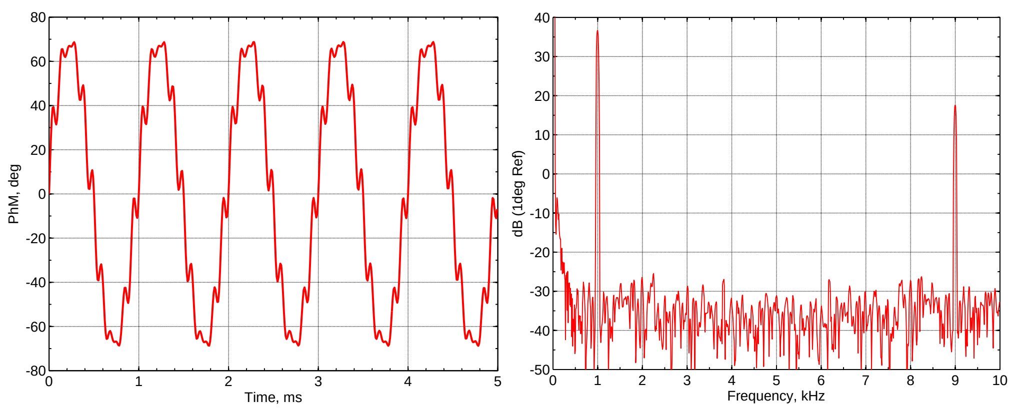
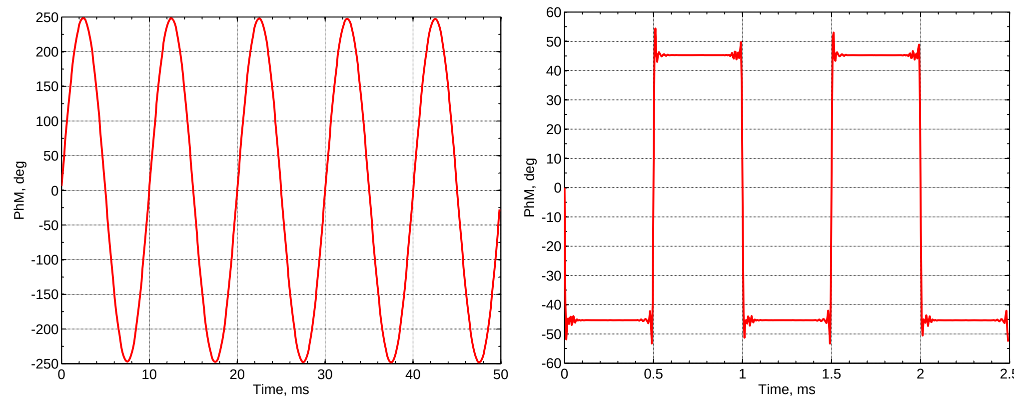


Figure 22: Demodulated PhM-signal (internal modulating source, sine waveform, frequency 1 kHz, , deviation 65°, center frequency 267 MHz)



(a) Sine modulating signal 100 Hz, Fc=267 MHz (b) Square modulating signal 1 kHz, Fc=6 GHz

Figure 23: Demodulated PhM-signal

Table 13: RS-232 interface signals pin-out for PC COM-port connection

PC (9-pin D-sub Male)		SG8 (9-pin D-sub Female)	
Signal	Pin #	Pin #	Signal
DCD	1	1	internally connected with pins 4 and 6
RxD	2	2	TxD
TxD	3	3	RxD
DTR	4	4	internally connected with pins 1 and 6
GND	5	5	GND
DSR	6	6	internally connected with pins 1 and 4
RTS	7	7	internally connected with pins 8
CTS	8	8	internally connected with pin 7
RI	9	9	not connected

update. To link the instrument to PC via USB, the software driver for USB-to-UART bridge is used, CP2102 chip. The latest version of driver for your OS can be downloaded from vendor's (Silicon Labs) site – www.silabs.com.

For RS-232 interface 9-pin D-sub, female connector is used. The pin-out is shown in table 13.

3 Operating Data

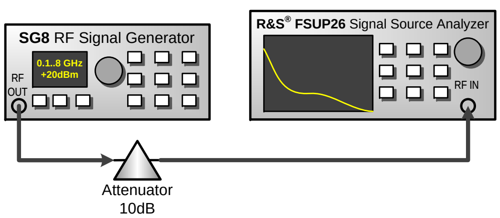
Operating data are listed in table 14.

Table 14: Operating data

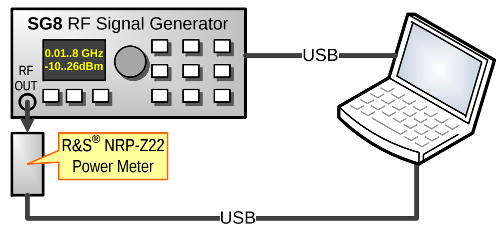
Parameter	Conditions	min.	typ.	max.	Unit
Power Supply	AC power supply, 47..63 Hz	85		264	V (AC)
	DC power supply	120		370	V (DC)
Power consumption			17	20	W
Inrush current	cold start @ 115V			13	A
	cold start @ 230V			25	A
Environment	Operating temperature range	0		+40	°C
	Storage temperature	−40		+71	°C
Vibration	sinusoidal, 5–150 Hz	2			g
Dimensions	height (with legs)			104	mm
	width (with legs)			246	mm
	depth (with connectors)			336	mm
Weight			3.5		kg
Recommended calibration interval			1		year

4 Test Setup

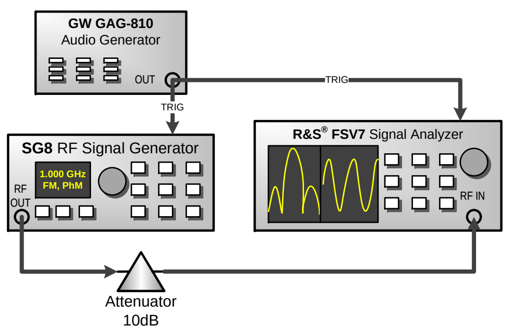
Figure 24a shows phase noise test setup, figure 24b – RF output signal level, figure 24c – frequency and phase modulation parameters, as well as RF signal level, frequency and phase switching processes in time domain. Frequency switching process were measured in bands 7.8125-15.625 and 15.625-31.25, which are within FSV signal analyzer's demodulation bandwidth. Since the original signal is generated in the range 4 to 8 GHz, the results can be applied to the entire range of the instrument.



(a) Phase noise and harmonic level test setup



(b) Output level measurement and calibration



(c) Modulation and switching process test setup

Figure 24: Test setup